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#13 Response 7-15-03

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of: **KANO, Takashi et al.**

Group Art Unit: **2812**

Serial No.: **09/941,982**

Examiner: **MULPURI, Savitri**

Filed: **August 30, 2001**

P.T.O. Confirmation No.: 7536

For. **METHOD OF FORMING NITRIDE-BASED SEMICONDUCTOR LAYER, AND METHOD OF MANUFACTURING NITRIDE-BASED SEMICONDUCTOR DEVICE**

SUPPLEMENTAL RESPONSE AFTER FINAL REJECTION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

July 8, 2003

Sir:

Further to the response filed on June 9, 2003, submitted herewith is a Declaration under 37 CFR §1.132 for consideration in the above-identified application.

Applicants had also notice some transnational errors in the Extended Abstracts and OHP sheets used in the 61st Autum Meeting 2000 of the Japanese Society of Applied Physics, filed with the response on June 9, 2003. A corrected version of the documents is attached hereto along with a marked copy of the original version to highlight the corrected errors.

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In the event any fees are due in connection with this paper, please charge our Deposit Account No. 01-2340.

Respectfully submitted,

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PATENT TRADEMARK OFFICE

Attachments: Declaration under 37 CFR §1.132 of Takashi Kano
Corrected Version of Extended Abstracts and OHP Sheets
With Marked-up Version

Partial Translation of Extended Abstracts
(The 61st Autumn Meeting, 2000);
The Japan Society of Applied Physics

5p-Y-1

High quality GaN film on low-temperature AlGaN buffer layer grown with high growth rate

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Microelectronics Research Center

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1. Introduction A GaN layer on sapphire is generally grown on a buffer layer grown at a low temperature, and it is important to optimize conditions of the buffer layer and the GaN layer grown thereon for improving the characteristics of a nitride-based light-emitting device. This time we have found out that a high-quality GaN film can be obtained by remarkably increasing the growth rate for a buffer layer, and report this.

2. Experiment GaN was grown on c-face sapphire by atmospheric pressure MOCVD in a two-step growth method. A buffer layer was prepared from AlGaN, and growth temperatures for the buffer layer and the GaN layer grown thereon were 600°C and 1080°C respectively. The growth rate for the buffer layer was varied

for evaluating the X-ray diffraction FWHM, surface morphology etc.

3. Conclusion Fig. 1 shows the relation between the growth rate for the AlGaN buffer layer and the X-ray diffraction FWHM. The X-ray diffraction FWHM was reduced as the growth rate was increased, and an excellent value of 248 arc sec. was obtained when the growth rate for the low-temperature AlGaN buffer layer was 25 Å/sec. (9 μm/h). The surface morphology was a mirror surface at this time, as shown in Fig. 2.

Fig. 1 Relation Between Growth Rate of AlGaN Low-Temperature Buffer Layer and Full Width at Half Maximum of X-ray of GaN Layer

Fig. 2 Surface Morphology

Translation of OHP sheets used in The 61st Autumn Meeting, 2000
of The Japan Society of Applied Physics

High Quality GaN Film on Low-temperature AlGaN Buffer Layer Grown with High Growth Rate

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Summary of Report

1. Background

2. Experimental Conditions

3. Evaluation of AlGaN Low-Temperature Buffer Layer Depending on Variation of Growth Rate
   - X-Ray Diffraction
   - Etch Pit Density
   - Sectional TEM

4. Characteristics of Blue Semiconductor Laser Employing High-Quality GaN Growth

5. Conclusion

Background

Conventional Low-Temperature Buffer Layer

No variations of characteristics with the growth rate have been examined.

Object

Extension of Optimum Condition Range in High-Quality GaN Growth

1. Employment of AlGaN Low-Temperature Buffer Layer
2. Quality Improvement of GaN Layer by Growth Rate Control

Growth Conditions

1. Structure of MOCVD Apparatus

1-1. Three Layered Flow Horizontal MOCVD Apparatus

1-2. Heating System by High-Frequency Oscillation

2. Growth Conditions for AlGaN Low-Temperature Buffer Layer

2-1. Substrate: C-Face Sapphire Substrate

2-2. Used Materials: TMAl, TMGa, NH3, H2 and N2

TMAl/(TMAl + TMGa) ≒ 0.5

2-3. Growth Temperature: 600°C

2-4. Thickness of Grown Film: 120 to 140 Å

3. Growth Conditions for GaN Layer

3-2. Used Materials: TMGa, NH3, H2 and N2

3-2. Growth Temperature: 1080°C

Structure of and Method of Evaluation for Evaluated Sample

Structure of Evaluated Sample

GaN Layer (4 μm)
AlGaN Low-Temperature Buffer Layer (120 to 140 Å)
C-Face Sapphire Substrate

Evaluation Method

1. Full Width at Half Maximum in X-Ray Diffraction Rocking Curve

   GaN(0002) Diffraction

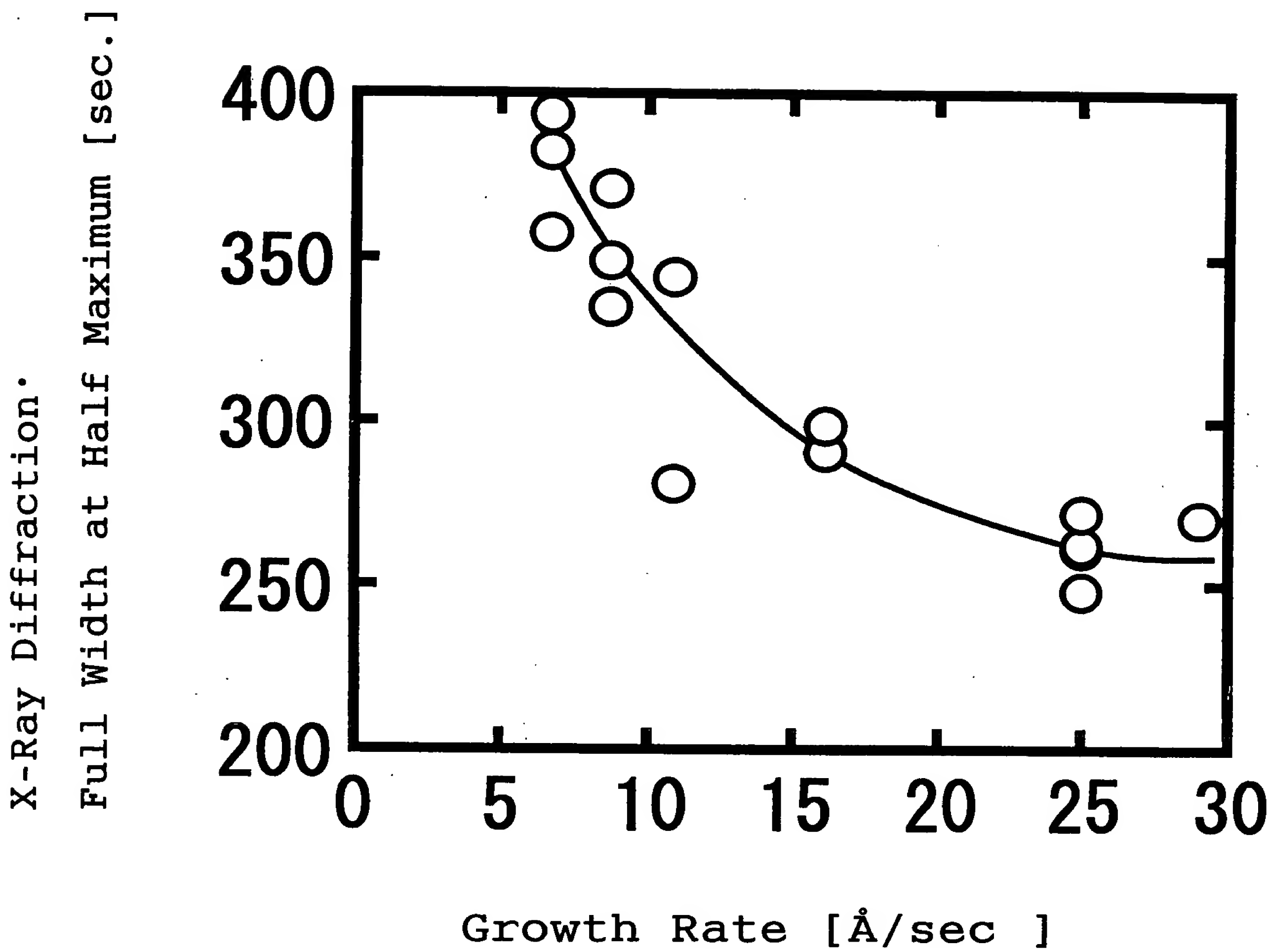
2. Etch Pit Density

   Etching Method NaOH:KOH = 5:1 (280°C)[1]

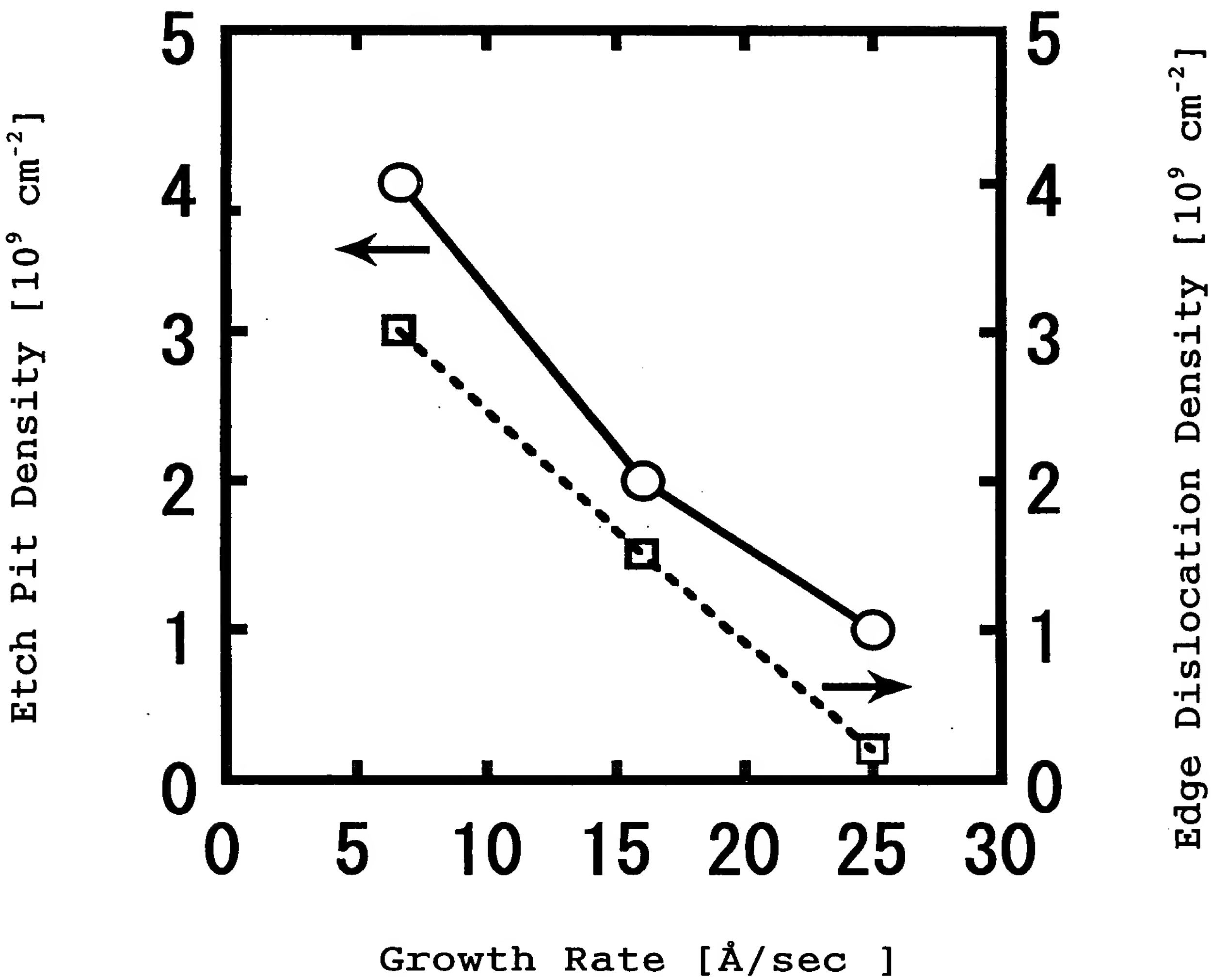
3. Sectional TEM Observation

(1) "Observations of etch pits in GaN layers" by Masayuki Hata et. al., Sanyo Electric Co., Ltd. Microelectronics Research Center

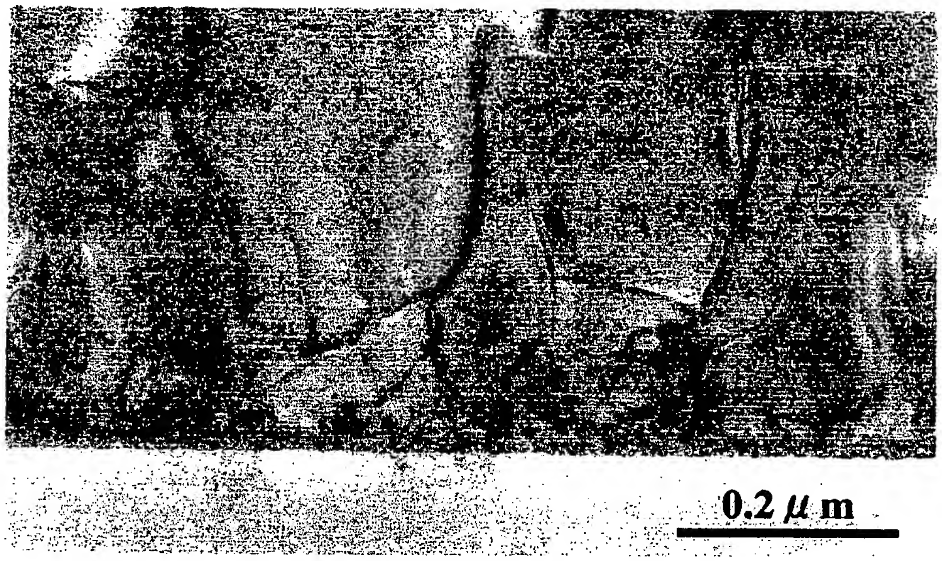
Extended Abstracts of the 57^{th} Meeting of the Japan Society of Applied Physics (1996), No. 1, p. 302



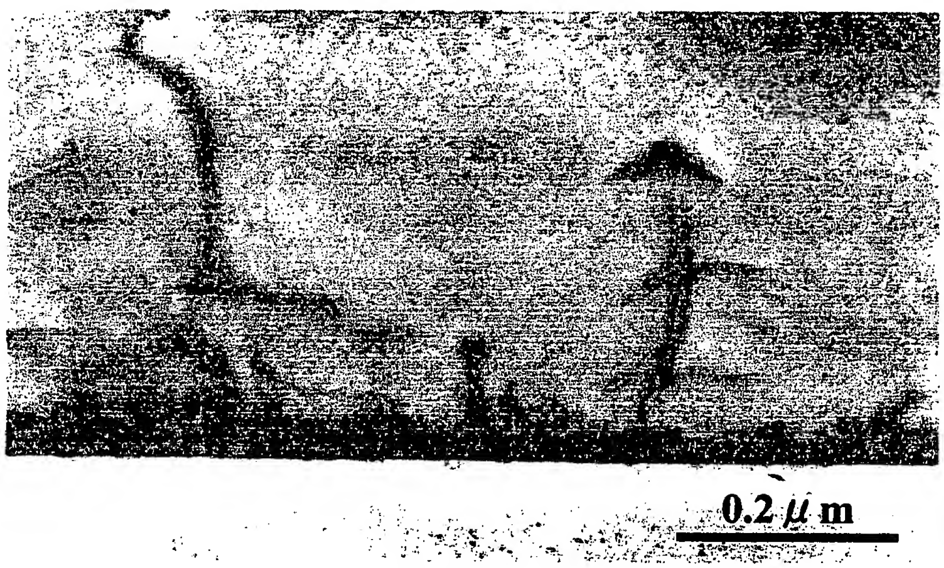
Relation Between Growth Rate of AlGaN Low-Temperature Buffer Layer and Full Width at Half Maximum of X-Ray of GaN Layer



Relation Between Growth Rate of AlGaN Low-Temperature Buffer Layer and Etch Pit Density of GaN Layer



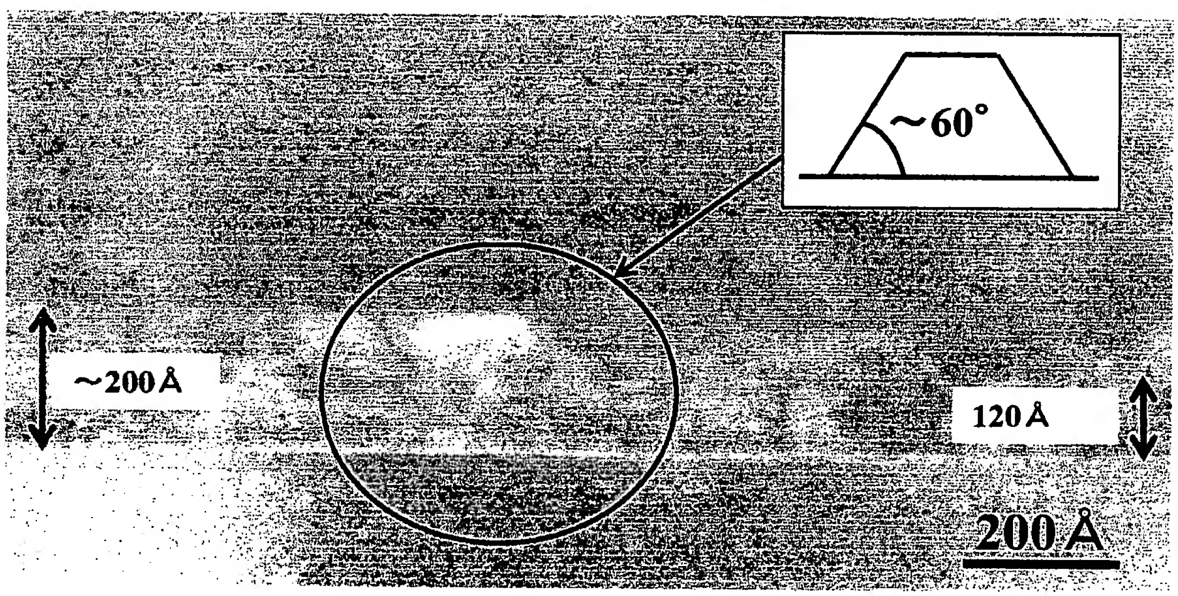
Growth Rate: 6.7 Å/sec.



Growth Rate: 25.0 Å/sec.

Sectional TEM Photograph of Interface Between Sapphire Substrate and GaN Layer (× 300,000)
[Sectional Photograph on GaN (11-20) Face]

Growth Rate: 6.7 Å/sec.



Growth Rate: 25.0 Å/sec.

Sectional TEM Photograph of Interface Between Sapphire Substrate and GaN Layer (×2,000,000) [Sectional Photograph on GaN (11-20) Face]

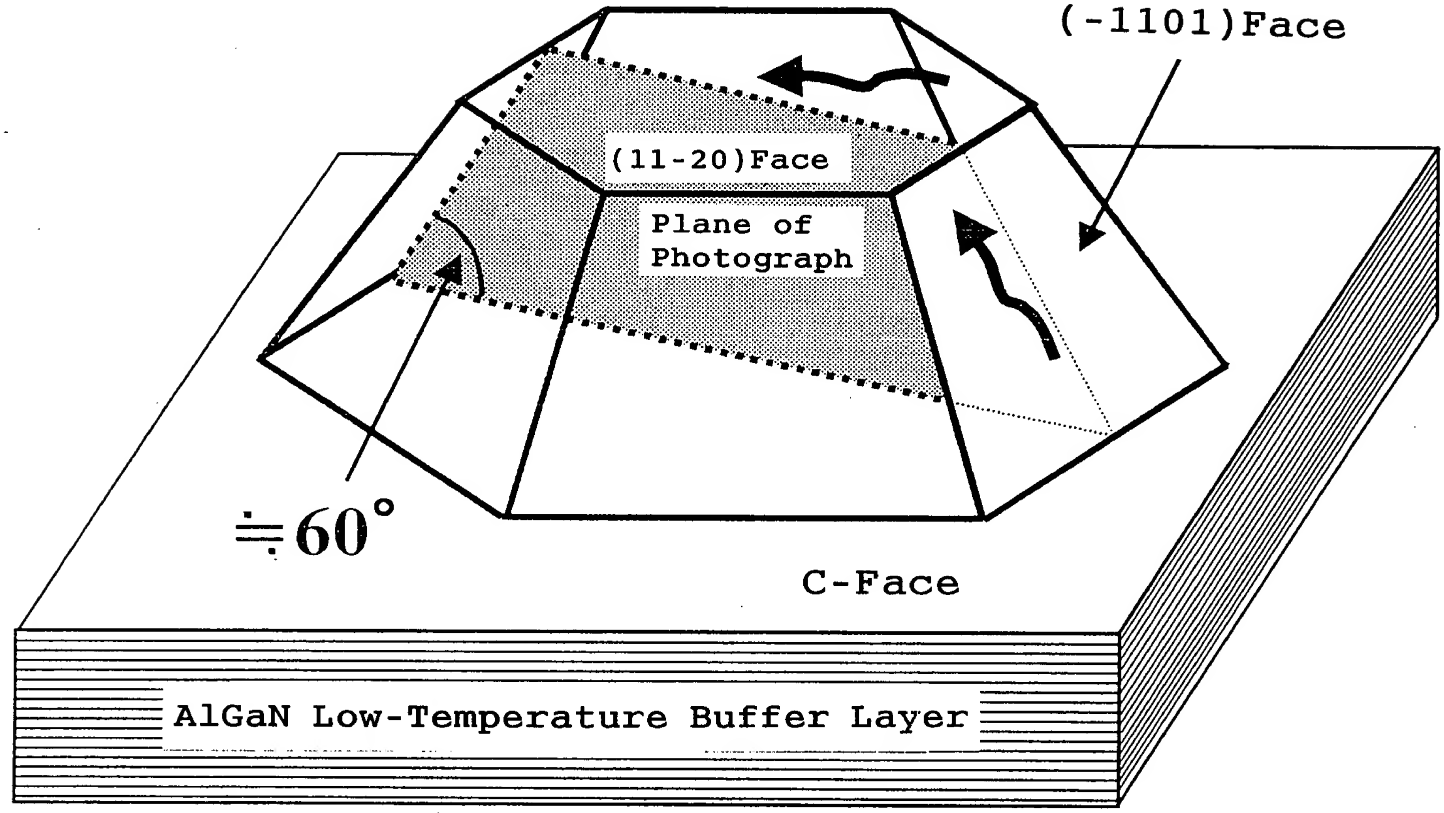
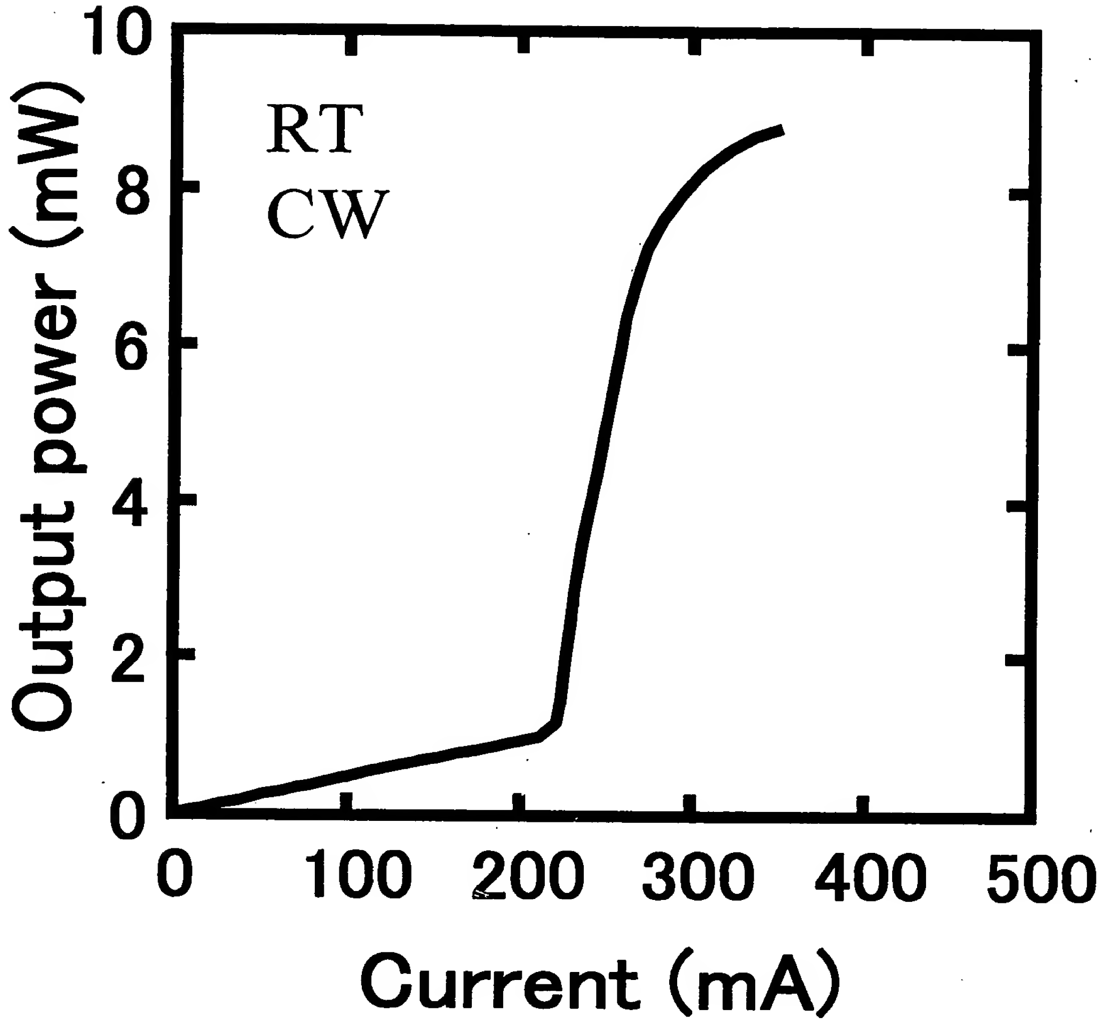


Image Diagram of Direction of Defect in Initial State of Growth of GaN Layer Employing Fast-Grown AlGaN Low-Temperature Buffer Layer



I-L Characteristics of GaN Laser Employing High-Quality GaN Growth

(Room-Temperature Continuous Oscillation)

Conclusion

1. Increasing growth rate of AlGaN low-temperature buffer layer to 25 to 30 Å/sec.

<u>GaN Layer</u>

·Full Width at Half Maximum of X-Ray Rocking Curve: 250 sec.

·Etch Pit Density: $1.0 \times [10^{9}\ cm^{-2}]$

↓

From sectional TEM on the interface between sapphire and GaN:

① Most of defects caused on the interface progress in directions parallel to the (-1101) face and the C-face.

↓

② The number of through defects in the C-axis direction decreases.

2. A blue semiconductor laser of room-temperature continuous oscillation was obtained through high-quality GaN growth.